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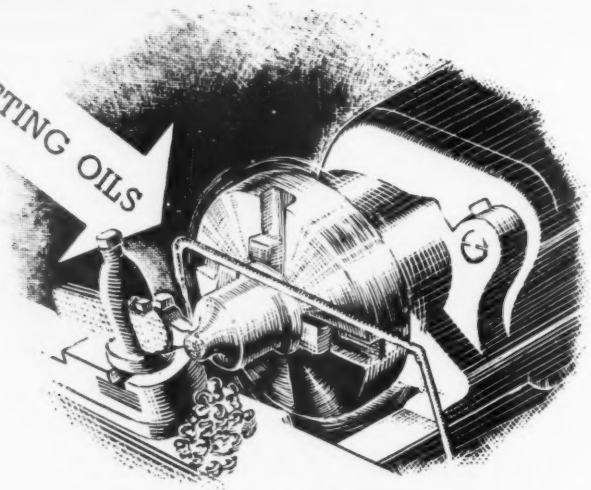

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RETROSPECT: REMINISCENCES OF THREE DECADES IN THE PETROLEUM REFINING INDUSTRY*

By A. E. DUNSTAN (*Past-President*)

IN recounting some personal reminiscences of the past thirty years, I do so because I fancy that now and again it may be of interest to look backwards and to contemplate the attempts that have been made, the successes that have been achieved, and the failures over which we have mourned.

The period since 1915 when I first entered the industry has indeed been one of outstanding interest. During it have occurred two devastating global wars, each, in turn, having revolutionary impacts on the science and technology of petroleum. It has witnessed catastrophic destruction on the one hand and a rare development of new technique and invention on the other. It has seen vast increase in knowledge, though not in wisdom. During this epoch there have come into being great associations such as the American Petroleum Institute and the Institution of Petroleum Technologists (now the Institute of Petroleum), whose purpose is the free interchange of knowledge and experience without the intervention of any iron curtain. It has seen the change over from sheer empiricism and rule of thumb methods to strictly scientific procedure. It has seen the replacement of technically untrained personnel by men of university upbringing and the application of scientific thought and method throughout the whole range of its endeavour. It has seen the establishment of vast reseach

* Paper read before London and Scottish Branches of the Institute.

organizations in America and in Europe, and in this period of time I myself have had the honour and privilege of assisting in the birth and upbringing of one of the largest of them.

It is astonishing to contemplate the state of the industry thirty years ago, but rather fantastic to look back a little further, in point of fact, to Sir Boverton Redwood's Cantor Lectures in 1886. The Founder-President of our Institute was able in the course of four lectures to comprehend the whole of the technology of petroleum known at that date, delving into the records of antiquity, summarizing the early history of mineral oil, developing the general geology of petroliferous formations, the methods of finding, winning and transporting the crude, and discussing the refining and applications of what, even then, was regarded as a most valuable natural product—in 1886 the U.S.A. produced rather more than 3 million tons of crude!

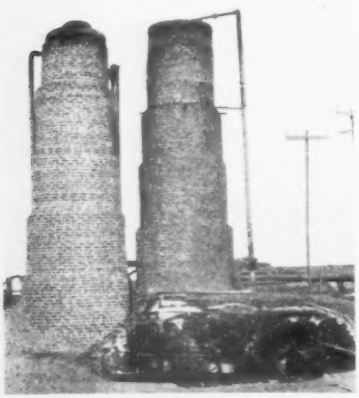
In his summing up, Redwood goes on to say: "By far the most important of the uses to which the products of petroleum are as yet applied is that of illumination", and he devotes quite a considerable part of his lectures to the description of the development of the "paraffin lamp", to candles and their wicks and, of course, to the discussion of flash-point, a subject in which he and Sir Frederick Abel were pioneers. He concludes by saying: "The use of petroleum products for illuminating purposes has often been said to have exercised a civilizing influence of an important character and there are those who contend that the degree of mental culture of a nation may be measured by the quantity of mineral oil consumed . . ."—a statement that reads somewhat grimly after our experience of two world wars.

But it is in the refining and production of a multiplicity of products that the really astonishing progress has been achieved. And first of all comes distillation. Redwood describes the simple pot still, much akin to the type of still to be seen in tar works, soon to be replaced by a series of continuously operated shell stills arranged so that the oil cascaded from one vessel to the next lower in the group.

In my first visit to Abadan in 1916 I saw the first use in our company of heat exchangers. Even at this time there was little attempt at fractionation as we now know it. Redistillation was the only method of securing merchantable gasoline and kerosine fractions of satisfactory boiling-point limits, although a simple type of Heckmann column was used for the lighter fractions.

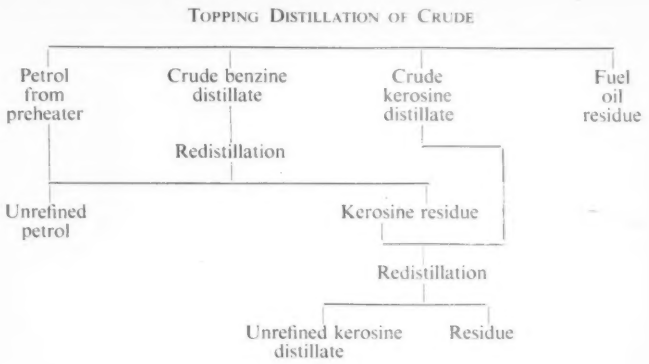
The pipe still was just on the way, yet I can remember a tubular still, invented by Lennard, that processed coal tar, and was certainly in operation at the South Metropolitan Gas Works, Greenwich, over thirty years ago.

An early and successful development was due to Trumble, who, just before my period began (1911), made a pipe still whose heated contents were fed into a tall columnar evaporator, fitted with perforated and imperforate baffle plates. In later models of this plant quite elaborate heat exchangers were employed.

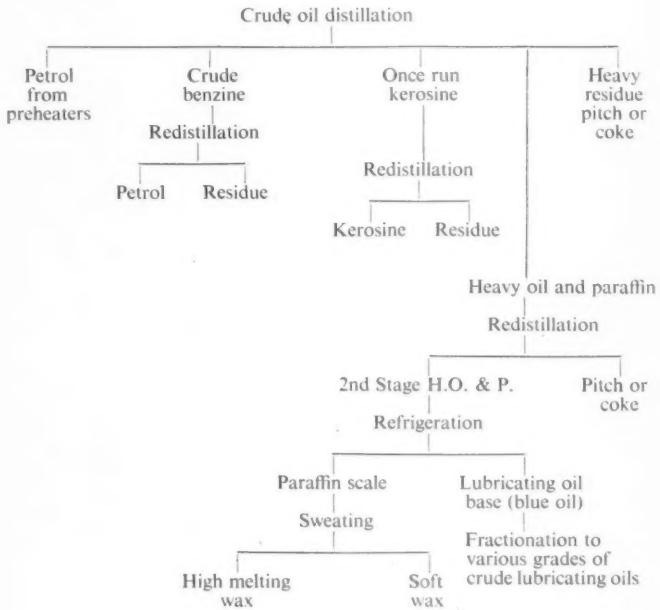


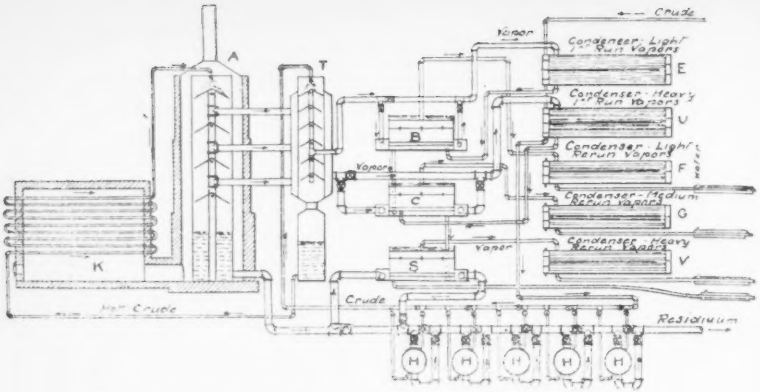
The original Trumble plant at Fellowes, California.

So simple a scheme as the following was typical:



A more complete scheme of this period is:



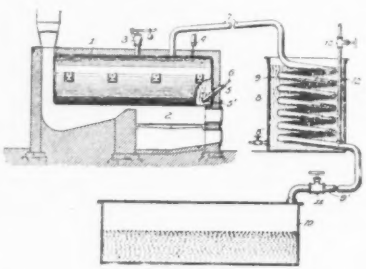


The Trumble plant elaborated by the addition of heat exchangers, etc.

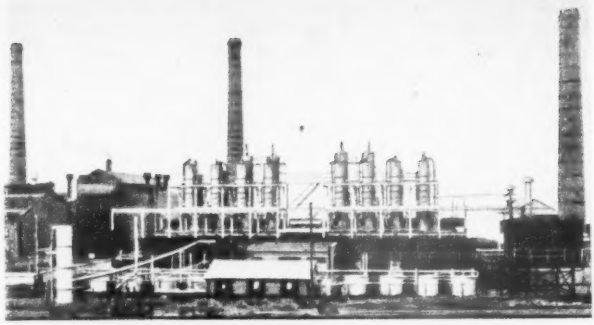
For a very full account of these early attempts at separation, reference should be made to Andrew Campbell's paper before the Institute in May 1916 and to Boverton Redwood's fourth edition of *Petroleum*, 1922. From this date onwards the combination of pipe still and fractionating column made steady progress.

From the remarkable diameter of 12 inches used in the early Trumble plant, the pipe decreased in size so as to increase oil velocity and minimize by greater and greater turbulence the inevitable deposit of coke. The importance of utilizing radiant heat absorption led to better furnace design so that full advantage could be taken of both the radiant and convection sections. At the same time there has been a rapid development of automatic recorders and controls. It is more than likely that the steady improvement in pipe-still design is the outstanding feature in distillation practice.

But the corresponding importance of fractionation must be acknowledged. Fractionation had already achieved a considerable degree of satisfactory performance in the alcohol and coal-tar industries, although these had not to contend with the great complexity of petroleum. The familiar bubble-cap tower derives from the Heckmann pattern used originally for the fractionation of light petroleum, and in turn based on the principles in vogue for the separation of alchohol from its aqueous solutions. The Heckmann tower was provided with a partial condenser (dephlegmator) to provide reflux. In modern systems the whole overhead is condensed and a proportion pumped back into the column for this purpose. The modern tower, with controlled reflux, side stream take-off, re-boilers and side strippers, has made possible the closest possible degree of fractionation. The final combination of pipe still – primary flash atmospheric tower – pipe still – vacuum



The Burton Process.



A battery of crude oil shell stills with dephlegmators.

tower, provides not only for sharp cutting but also for the complete separation of the vaporizable components of the crude oil.

Whereas at the commencement of this epoch natural gas was, in effect, largely a waste product often only of a nuisance value, the intervening years have seen the fractionation process applied to this the lightest fraction of petroleum, and to-day the separation of propane and butane (and *iso*butane) is effected by super-fractionating columns operating under pressure. It should not be forgotten that very intensive study, chiefly in the United States, of the theory of distillation and of fractionation has been carried out to the great advantage of the industry.

Cracking

At present, cracking, reforming, hydroforming, catalytic cracking, viscosity breaking—in other words, the thermal treatment of petroleum residue and distillates—plays the most spectacular part in refinery operations.

I was very soon brought into contact with cracking, for early in 1915 the then Anglo-Persian Oil Company was given the task by the Government of operating the Hall process at Thameshaven. This was a vapour-phase system, working at 750° C. and about 100 lb. pressure. The cracking of a heavy Persian distillate (50 per cent on crude) was achieved by a single passage through a nest of 1-inch pipe, followed by expansion into a wider vessel in which the thermal decomposition was said to take place. However, the tubular system regularly choked up. The ostensible purpose of the installation was the production of toluene and certainly this occurred—the gasoline fraction from the operation contained about 16 per cent of toluene. The product, however, was so complex and there was such a high content of very reactive unsaturateds that the isolation of the pure aromatic hydrocarbon was virtually impossible, and anyhow the cost of it would have been prohibitive. The process was dropped, curiously enough, about the time when the direct fractionation of Borneo benzine provided very considerable amounts of perfectly pure toluene.

There was a spate of processes akin to that of Hall—all vapour-phase and most of them making use of some sort of "catalyst"—ranging from iron nails, nickel powder, and other metals to bauxite, porcelain, and sand. Names associated with these vapour-phase processes are Rittman, Lucas, Ramage, and Greenstreet.

I made a thorough examination at this time of the literature of cracking (*J. Inst. Petrol. Techn.*, 1916, **3**, 36–120)

in collaboration with F. B. Thole and E. L. Lomax, and the curious will find therein much astonishing cracking lore. Very interesting is the patent granted 100 years ago to James Young for increasing the yield of kerosine from gas oil by distillation under a pressure of 20 lb. I have seen at Middleton Hall an old drawing, showing in the block plan of Uphall refinery a section labelled "cracking plant". And mention should certainly be made of the celebrated patent of Redwood and Dewar (1889) which describes a process for increasing the field of lighter oils from heavier by distilling and condensing under pressure. This surely is the master patent.

Cracking processes and the refining of the product occupied our attention at Sunbury for many years. We soon turned our attention to high-pressure technique. In one abortive attempt the oil was passed through heated tubes very slowly, contrary to all previous views. In another an oscillatory surge was applied to a slowly moving column of oil. A visual cracking plant was built of silica. Altogether a number of scatter-brained experiments were set up—impracticable but still giving staff some first-hand and first-rate experience.

Actually we were outstripped by the urge of production and shortly liquid-phase plants operating on the Dubbs' and Cross systems were at work in our refineries.

Although Redwood and Dewar's patent may be regarded reasonably as basic, yet it primarily was concerned with the production of kerosine and not gasoline. Precisely the same method of procedure was adopted in the pioneer patent for gasoline manufacture—that is, the Burton process (1913).

There can be no doubt that Burton achieved a triumph of chemical engineering applied to petroleum technology. Distillation of gas oil at about 400° C. and 100 lb. pressure in shell stills is a serious proposition, and yet many years elapsed before a fatal accident occurred.

From Burton's original boiler still to tubular heaters and reactors, soaking drums or, in general, spaces in which carbon deposition can occur away from the highly heated zone is an obvious development.

It must be realized that the ever-growing demand for motor spirit and the relative disparity in price of gasoline and the heavier fractions brought about the almost phenomenal development of big-scale cracking. And further, that the process, at first merely a quantity-production, soon became a quality-production as the need for higher octane spirit developed.

So much is this the case that we have now arrived at the remarkable state of affairs where straight-run gasoline is no longer in the picture and modern motor, especially aviation, spirit is a blend of natural gasoline, cracked and reformed gasoline, and special hydrocarbons synthesized and made use of for their high octane value.

A word may be said here about octane numbers. I had the good fortune to be present at the meeting in America, 1930, where Graham Edgar first developed the idea of the *n*-heptane-*iso*octane scale and the C.F.R. engine-testing technique. The Institute was able to collaborate with the A.S.T.M. and the American Society of Automotive Engineers, and that collaboration has, I am glad to see, persisted. As a mark of good fellowship James Kewley, F. H. Garner and I were co-opted on the A.S.T.M. Committee D–2.

Treatments

Very early in our work at Sunbury we were faced with refining problems. At that time all our slumped untreated benzine was sold as such to the Asiatic Petroleum Company and was finished in their Suez refinery by conventional acid and soda. We were anxious to refine this material in Abadan and soon realized that it was essential to find out what

particular components we wished to eliminate. The benzine had a high sulphur content (about 0·1 per cent) and a foul, rank smell. The familiar litharge (plumbite) treatment certainly sweetened it but left the sulphur content unchanged. Oxidizing agents were effective. We even contemplated using (and manufacturing) sodium permanganate—this, incidentally, oxidized the toluene content into benzaldehyde. To cut a long story short, a very complete examination showed the presence of mercaptans and thio-ethers. Sodium or calcium hypochlorites did the trick and our first Sunbury patent was issued in 1918. We found it possible to run sulphur content down to 0·01 per cent, but it was not till much later that we found the deleterious effect of sulphur on lead response.

By now the chemistry of these and similar treatments—including that of the old stand-by sulphuric acid—is thoroughly well known. It should always be realized, however, that "sweetening" does not connote sulphur removal—it merely brings about the conversion of odoriferous mercaptans into higher boiling and relatively odourless disulphides.

It was soon found that cracked gasolines—specially vapour-phase material—was more recalcitrant to treatment than the straight-run material. The standard methods are effective, however, but a variety of other processes has been developed in the meantime. For example, mercaptans may be selectively dissolved out by such solvents as soda.

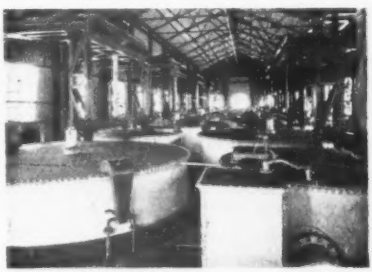
Quite early in our work we met some success by passing crude cracked gasoline over freshly ignited bauxite followed by distillation to remove the high boiling polymers produced.

But bauxite was by no means unfamiliar to us. It had been used successfully by the Burmah Oil Company in Rangoon for decolorizing kerosine, and I saw it at work on a similar task in Abadan in 1916. Being interested, however, in sulphur removal and having realized that freshly ignited bauxite was an absorbent of high quality, we set up an experiment to discover whether or not it would absorb such polar bodies as thio-derivatives. In this we were successful and were able practically to completely desulphurize the highly sulphurous Persian kerosine.

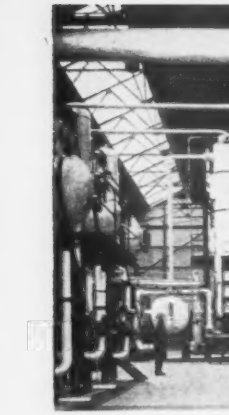
It was by no means easy to roast bauxite on the works scale, and this apparently simple method of refining was only partially successful in the refinery. It is, however, of interest that bauxite is still on the map and there are, in fact, some recent American patents covering its use. It probably is one of the earliest used mineral adsorbents and a predecessor of the innumerable clays in vogue to-day.

Solvent Extraction

Early in 1915 my company became interested in the Edeleanu process, which depends on the selective solubility of aromatic hydrocarbons in liquid sulphur dioxide. I got to know Edeleanu quite well, and he told me of his efforts to refine Roumanian crude kerosine into a non-smoking water-white burning oil. The raw material is partly aromatic in nature and although refinable by sulphuric acid (and/or oleum) it experienced quite impossible losses. A brilliant shot led to the application of liquid sulphur dioxide, and this turned out to be the basis of a whole series of selective solvent, especially when applied to the



Holley-Mott continuous counter-current washers.



Edeleanu plant for kerosine refining.

refining of lubricating oils. I well remember a meeting in Chicago—in November 1928—when the problem of the utilization of acid tar was being discussed. I sat next to Edeleanu, and I got up and said to the chairman, "Why worry about acid tar? Here is, next to me, a man who has rendered acid refining superfluous."

Whilst the raffinate is a highly refined burning oil, the extract is of a notably aromatic character and the lighter fractions of it can readily be incorporated in gasoline as an anti-knock component. In effect, to-day, this method is used for segregating aromatics even from gasoline fractions, and it was during the first world war that I suggested this application and set up experimental plant at Dartford for producing a rich toluene cut from Persian benzine.

Out of this work of Edeleanu undoubtedly arose modern methods of refining lubricating oils, using a veritable multiplicity of solvents not only such as liquid propane that separate oil from bitumen, but solvents selective in their capacity for removing the highly polar and unwanted concomitants of the oil proper. Such are furfural, phenol, chlorex, and nitrobenzene.

The results of our early work at Sunbury were soon seen in the large-scale operation of the process in the refineries, first for kerosine and much later for lubricating oil.

Of some interest in connexion with the application of bauxite is a test we developed at Sunbury about 1920. The apparatus made use of what was called the ergometer and it consisted of a cylinder containing 20 g. of the freshly ignited mineral and a thermometer immersed therein. On adding a specific amount of kerosine there was an immediate rise in temperature, measuring the heat of adsorption. The better the bauxite, the higher the temperature rise. A very full account of bauxite refining is given in my Cantor Lectures, Royal Society of Arts, 1928.

Natural Gas and the Lower Gaseous Hydrocarbons

I remember on the occasion of my first visit to the Persian oilfields being impressed and oppressed by the magnitude of our gas problems. The Masjid-i-Suleiman field was then in the early stages of development. There was a high gas-oil ratio and a content of hydrogen sulphide that reached 12 per cent in some wells. I had very early been attracted to the idea of "cracking" hydrocarbon gas, but it was not till we were able to obtain the welcome co-operation of the late Professor Wheeler of Sheffield University and to take advantage of the wealth of information possessed by his research school that we were able to proceed with our investigations. The results may be summarized:

(*a*) *Pyrolysis for the production of aromatic hydrocarbons;*
(*b*) *Pyrolysis for the production of olefinic hydrocarbons;*
(*c*) *Polymerization and condensation of olefinic hydrocarbons to give low boiling liquids in the gasoline range.*

So much so, that I was able to report in 1933 (*J. Soc. Chem. Ind.*, 1933, **52**, 938) "the olefinic content of cracked gases may be practically quantitatively converted

into high anti-knock fluid hydrocarbons".

Reviewing recent advances it will readily be seen that the nuisance value of natural and refinery gases has largely been eliminated. For instance, methane may be a ready source of hydrogen, as a source of heat both industrial and domestic, as a chemical raw material for formaldehyde, methyl alcohol, acetone, acetaldehyde, chlorinated solvents, nitro-derivatives, and the like.

But it is the reactivity of the olefinic content of cracked gas (and the pyrolysis product of the lower hydrocarbons) that has made possible the synthesis of specially light octane aviation spirit. The most spectacular of these newer syntheses was the subject of a paper from Sunbury in 1938 which described what is now known as the "alkylation" process, i.e. the direct union of *iso*butane with the butenes and di-*iso*butene in the presence of a catalyst such as sulphuric acid. The production of *iso*octane by this means is by far the most important application of the process.

Actually, earlier than alkylation came the preparation of *iso*octane by the reactions: *iso*butene – di-*iso*butene – *iso*-octane. But the need for *iso*butane led to the need for isomerization of *n*-butane and this was soon achieved by catalytic reforming over an aluminium chloride catalyst with a promotor such as hydrogen chloride. In any case, apart from their use in alkylation, the *iso*paraffins have far higher anti-knock qualities than their normal isomers.

Straight chain paraffins containing six or more carbon atoms were found to be readily cyclized, and from the *cyclo*-paraffins dehydrogenation led to the formation of aromatic hydrocarbons, thus *n*-octane – dimethyl*cyclo*hexane – *o*-xylene. And all this can be achieved in the process known as hydroforming when straight paraffins in the presence of excess of hydrogen contacted with appropriate catalysts yield a highly aromatic product.

Solvent extraction has already been mentioned as a means of removing aromatic hydrocarbons from straight-run distillates of petroleum, and so we may arrive at the modern high octane fuel by a combination of these various processes.

Additives

A word might be said here about those additives which in minute proportion very materially increase anti-knock value. It would be unnecessary to mention tetra-ethyl lead (1922), but quite early in our history at Sunbury there were intensive efforts to achieve this end. Some fifteen years ago we had the privilege of working with the late Sir Jocelyn Thorpe, some of whose students are still with us. A very thorough search of possible and probable anti-knock agents was made. It is sufficient to say here that none of the materials investigated was any way near tetra-ethyl lead in its effect on motor fuel, but some interesting results were obtained with tellurium derivatives and some aromatic amines. Incidentally we carried out considerable research on dopes designed to inhibit gum formation.

Modern Aviation Spirits

As examples of synthetic aviation spirits compared with the straight-run material, the following may be quoted:

Straight-run		
A.P.I. gravity	68.4°	
10% at	149° F.	
90% at	220° F.	
End point	254° F.	
Octane No., A.S.T.M.	61	
An early blended spirit 1939		
*iso*Octane	28	per cent.
Pyrolysis benzol	17	,, ,,
Topped aromatic extract ex kerosine	10	,, ,,
*iso*Pentane	10	,, ,,
Straight-run spirit	35	,, ,,
T.E.L.	3	c.c./U.S. gal.
Octane No., A.S.T.M.	89	
A blend circa 1940		
Hydrocodimer	38	per cent
*iso*Octane	10	,, ,,
Pyrolysis benzol	22·5	,, ,,
Aromatic extract	5·0	,, ,,
*iso*Pentane	15·0	,, ,,
Straight-run spirit	9·5	,, ,,
T.E.L.	3·3	c.c./U.S. gal.
Octane No., A.S.T.M.	100	

And still later

Alkylate	25 per cent.
Aromatic extract	25 ,, ,,
*iso*Heptane	20 ,, ,,
*iso*Hexane	15 ,, ,,
*iso*Pentane	15 ,, ,,
T.E.L.	4 c.c. per U.S. gal.

Although these formulae belong to yesterday and to-day, yet it is true that there was a considerable amount of pioneering work that goes back quite a long way into the period of the three decades, and especially in the direction of super-fractionation.

Synthetic Chemicals from Petroleum

All through the period under review there were hopes and expectations of the founding of an industry analogous to that of the coal-tar derivatives—it was well known, for example, that there was nothing in coal-tar that could not be obtained from mineral oil and many materials that could not be produced from tar inherent in petroleum.

The list of products to-day is formidable, and it would be an impossible task even to discuss in the briefest possible way these multitudinous offshoots of the petroleum tree. Suffice it to say that in the current literature the story is amply told and to refer the reader specially to R. P. Russell's recent addresses to the Institute on synthetic rubber, plastics and resins (*I.P. Review*, 1947, 1, 222) and Cadman Memorial Lecture, and to my own paper, "Chemistry and the Petroleum Industry" (Institute of Chemistry, May 1941).

Hydrogenation

Just a brief reference should be made to the beginnings of the work on the reduction of coal and heavy petroleum residues by means of hydrogen catalysts and very high pressures.

In this branch of technology grateful acknowledgment should be made to the veteran Ipatiev.

Ipatiev is the father and the begetter of high-pressure technique. In his classical work ("Catalytic reactions at high pressures and temperatures") he has described his pioneering researches on which were surely established all later developments.

It has been my good fortune to know and appreciate both Ipatiev and Bergius and still later other and younger investigators in these fields—I refer to K. Gordon of Billingham and R. T. Haslam in America.

The high-pressure hydrogenation of coal, mineral oil residue, and lubricating stock has been well established in the period under review. The technique of the process is so well known that there is little need for description and it may be regarded even as a closed chapter in the history of petroleum.

Any retrospect like this, trying to look back on current thought and research to the foundations laid years ago, should properly end with a prospect of things to come.

Petroleum is likely to become a formidable competitor to coal-tar as a source of chemical products—solvents, plasticizers, explosives, dye-stuffs, drugs, and plastics. Further, it will produce the familiar and conventional aromatic hydrocarbons more readily and more cheaply than will tar.

Synthesis such as that of glycerol from propylene suggest that the reactivity of the olefins has not yet been fully explored, and the application of formerly wasted by-products to detergent manufacture show once again the versatility of our industry.

An ever-lengthening vista is opening out for the application of petroleum and its products to our modern civilization. The picture changes, new ideas are developed, motor and aviation spirit may yield their places to jet-propulsion fuels, the compression-ignition engine may replace the petrol-driven machine, new additives may revolutionize lubrication, the immense variety of plastics may well affect both our homes and our out-of-doors environment. Synthetic rubber and its applications may have an

impact on nature's material much as synthetic indigo affected the cultivation of the natural product.

Chemically manufactured foodstuffs —such as fats built up from synthetic glycerol and the oxidation product of straight-chain paraffins—are just round the corner. An ever-increasing world population may well demand the help of petroleum chemistry to world-wide shortages.

And it is rather startling to realize that, apart from metals, most of our industrial commodities have been and are, in fact, of vegetable or animal origin. Textiles, paints, varnishes, solvents, dyes, drugs, rubber plastics—the list is endless. To-day sees the beginning of derived petroleum industries in which all of those and many more are of laboratory origin and it is vastly interesting to note that more than once a chemical derivative has been synthesized in the laboratory and no obvious use lay ready for it at the moment—but sooner or later this unwanted and unwelcomed stranger found a home. I need only mention glycol, which to-day brings in a revenue of three million pounds sterling.

One cannot doubt that these new syntheses, still as yet in their early childhood, are destined to expand surely and rapidly to a scale and scope almost impossible to envisage.

GERMAN OIL PRODUCTION

Crude oil production in Germany during 1948 is reported as 635,240 metric tons, an increase of 58,623 metric tons, or about 10 per cent over the 1947 total of 576,617 metric tons. Details for the principal areas are:

	1948	1947
	Metric tons	
Emsland	167,847	114,067
Hannover	370,086	363,630
Schleswig Holstein-Hamburg	91,267	92,645
Baden	6,040	6,275
	635,240	576,617

SOUTH WALES BRANCH

On November 2, 1948, at Britannic House, Llandarcy, a paper entitled "Pressure vessels" was read by A. C. Vivian, of the Anglo-Iranian Oil Co. Ltd., to the South Wales Branch of the Institute. There was a good attendance of Branch members, together with a number of visitors, amongst whom were factory and insurance inspectors and others associated with the construction and use of pressure vessels. A lively discussion followed, in the course of which H. C. Brown, chief engineer of the Ocean Accident Insurance Corporation, and H. M. Pemberton, of Lloyds, London, and Professor O'Neil, head of the Metallurgical Department, Swansea University, spoke.

On December 2, 1948 a joint meeting with the South Wales Branches of the Institutes of Fuel and Petroleum was held at the Institute of Engineers, Cardiff, when J. A. Oriel, C.B.E., M.C. (a vice-president of the Institute of Petroleum), presented a paper entitled: "Some aspects of the oil industry".

After dealing with the past history and present position of the petroleum industry, consideration was given to the future trends, with analyses of the three cases in which the oil industry is going through changes, namely, the arrival of the gas turbine, increased application of the diesel engine, and the whole economic outlook on fuel and power since the end of the second world war. In discussing the economic situation, the point was made that coal and oil are not competitive but complementary.

The meeting was well attended and an interesting discussion followed.

High Vacuum Pumps.—A new catalogue of "Speedivac" rotary high vacuum pumps is available from W. Edwards & Co. (London) Ltd., Lower Sydenham, London, S.E.26.

COUNCIL COMMENTARY

THE first Council meeting in 1949 was held on January 12 at Manson House, with an attendance of twenty, apologies for absence being received from a further twenty-three.

The minutes of the December meeting were confirmed and signed, but before dealing with matters arising, Mr H. C. Tett reported a sad event, which was that Dr Simon Papp, a Fellow of the Institute for the last twenty-five years, had been condemned to death in Hungary.

The President had sent a cable asking for clemency on the grounds of his eminent services to science. It was understood that the Geological Society and other scientific societies had taken similar action. Council approved the action taken by the President.

Matters arising from the minutes were then dealt with, and we were informed by the General Secretary that we were unable to register our proposed monogram because we were not a trading concern for the purposes of such registration.

A lively discussion followed a protest from Mr Parker against our alteration of this monogram at a previous Council meeting. Mr Parker has done more than anyone to bring about the adoption of a monogram and crest for the Institute, and we had to sit humbly at the feet of Gamaliel whilst he explained his objections, which apparently were, among other things, that in seeking to get rid of ambiguity by means of our small alteration, we had, in fact, destroyed its monogramicity, as it were, much to his dismay.

It was agreed that whatever was now decided should be embodied in a master copy, in drawing ink, which should be dated and filed along with the relevant minutes.

Reports by Election, Engineering, Publication, and House committees were then presented and approved, the House Committee report dealing with staff changes.

Nominations for Council were disclosed as follows:

V. Biske	*E. C. Masterson*
R. J. Bressey	*R. G. Mitchell*
C. D. Brewer	*J. A. Oriel*
F. L. Garton	*H. W. Sanson*
H. S. Gibson	*R. B. Southall*
J. G. Hancock	*H. C. Tett*
E. W. Hardiman	*T. C. G. Thorpe*
C. H. S. Haygarth	

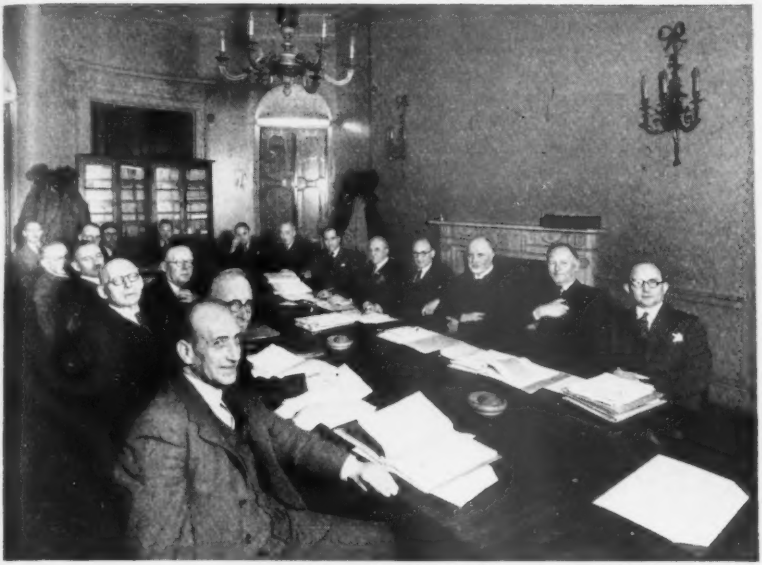
The amount of information to be supplied about members on the ballot sheet was discussed again, it being agreed that the Honorary Secretary should scrutinize the ballot papers before they were issued, with a view to ensuring uniformity in presentation of details concerning candidates, the ballot list including also details of existing Council members.

It was further agreed that a detailed list of candidates for Council, giving details of their appointments and scientific qualifications, should be published in the *Review* (see pp. 47–8). It was confirmed also that figures showing the attendance of Council members at Council and the various committees of which they were members should be included in the draft annual report for the consideration of Council prior to circulation at the Annual General Meeting.

It was decided that the date of the Annual General Meeting should be Wednesday, April 27, and the time 5.30 p.m.

The President further reported that he had sent congratulations to Dr R. E. Priestley, Mr R. Frazer, and the Lord Mayor of Manchester in connexion with their New Year honours.

A letter from the General Secretary of the Institution of Fire Engineers, suggesting closer liaison between them and the Institute of Petroleum on matters dealing with fire engineering was welcomed, and Mr E. Thornton was deputed to reply to the letter.



THE COUNCIL, 1949

In the picture below, the Council of the Institute is seen hard at work on the affairs of the Institute, while above, they rest for a moment from their activity for a more formal picture.

The General Secretary said that he had been approached by the Secretary of the Fourth Empire Mining and Metallurgical Congress, with a view to arranging visits to petroleum refineries by members of the Congress. It was stated that arrangements were already in hand to this effect.

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NEW TANKER FOR SHELL FLEET

Another 28,000 ton d.w. tanker is to be built by Messrs Swan, Hunter at Wallsend-on-Tyne. This is the second vessel of this tonnage now on order with the firm for the Shell fleet and brings the total number of 28,000-d.w. tankers to be built for Shell up to four. Two others are under construction, by Harland and Wolff at Belfast and by Cammell, Laird at Birkenhead.

The newly-ordered tanker, which is to cost more than £1,000,000, is expected to be ready for service by the end of 1951, about six months after the sister ship now building in the same yard. She will be constructed to Shell Marine Department specification which will include oil-firing, water-tube boilers and propulsion by geared turbines. Machinery to be installed in the new tanker will be supplied by the Wallsend Slipway and Engineering Company, a subsidiary of Swan, Hunter.

PETROLEUM IN PARLIAMENT

Carbon Black

In a written reply on January 18 the President of the Board of Trade said that plans are well advanced for the erection in the U.K. of plants to produce carbon black, using American processes. One company is considering the possibility of using home-produced tar products as their raw material.

Fuel Oil Consumption

The Minister of Fuel and Power, in a written reply on January 19, said that the total annual fuel consumption by power stations will probably be 5 million tons of solid fuel and 60,000 tons of fuel oil greater in 1952 than in 1948. He was informed, he said, that the average thermal efficiency of the new power stations, after allowing for power used to drive station auxiliaries, was estimated at 26 per cent.

Fawley Refinery

Mr T. C. Skeffington-Lodge asked the Minister on January 18 whether he would make a statement about the proposed establishment of a foreign-controlled oil refinery near Southampton; and if he would give an assurance that its erection would in no way adversely affect the trade of British refiners.

The Minister of Fuel and Power, in a written reply, presumed that the reference was to the expansion of the Anglo-American Oil Company's refinery at Fawley. He said that if this project was carried out the company would import crude oil to refine here instead of importing refined products to meet their market in the U.K. It would not, therefore, affect the position of other refiners.

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"Links"—It is ten years since this house magazine of Alexander Duckham & Co. Ltd. last made its appearance. The first issue of volume eight is now out, and it is planned to publish three issues yearly. It contains interesting articles on subjects as diverse as opencast coal and the fascination of wines.

THE WORLD FROM THE AIR

An interesting exhibition of aerial photographs and equipment for their taking was held at the Alpine Club's Gallery, London, between February 8 and 19, 1949. Organized by the Hunting Group of Air Survey Companies, it was opened by the Rt Hon Lord Pakenham, Minister of Civil Aviation, who was introduced by the Rt Hon Lord Brabazon of Tara, M.C., P.C. A vote of thanks to the Minister was proposed by the Rt Hon Lord Rennell of Rodd, K.B.E., C.B. Their lordships all stressed the importance of aerial photography in the exploration of new sources of raw materials and in the rapid surveying of the earth's surface to provide accurate and up-to-date maps.

The diverse uses of aerial photography were illustrated by some excellent photographs, and the apparatus shown by various manufacturers included cameras, mapping equipment, contour equipment, etc.

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GERMAN INTELLIGENCE REPORTS

By arrangement between the Association of British Chemical Manufacturers and the Board of Trade, work has been proceeding on a card index of the information contained in the various C.I.O.S., B.I.O.S. and F.I.A.T. reports which have resulted from visits by technical teams to German industry.

H.M. Stationery Office is prepared to produce this index in purchasable form, provided a guaranteed sale can be assured. The index will be alphabetical as regards products, the price for the seven volumes being £5 5s., and those interested are asked to inform, without delay, the Intelligence Officer of the A.B.C.M. at 166 Piccadilly, London, W.1. The card index may be seen at the Technical Information and Documents Unit, Board of Trade, 40 Cadogan Square, London, S.W.1.

"STRUGGLE FOR OIL"

This 20-minute film, No. 25 in the *This Modern Age* series produced by the J. Arthur Rank Organization, particularly stresses the importance of the Middle East as a major source of crude petroleum. The early scenes include shots of the lamp given away in China to create a demand for oil, of John D. Rockefeller, and of the first well in Iran. Examples of the importance of petroleum in warfare are given, and it is shown how the German strategy was designed to gain oil for a long war.

With peace came still greater demands for oil, and the United States found it necessary to import more oil than she exported.

Thus, the Middle East became the centre of interest. Some excellent views are given of fields and refineries in Iran, Iraq, Kuwait, Bahrein, and Saudi Arabia. The film (35 mm talkie) is distributed by General Film Distributors Ltd., and will be available later in a 16-mm version through G.B. Instructional Ltd.

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LARGEST MARINE DRILLING RIG

WHAT is believed to be the largest marine-type diesel electric drilling rig in the world has been built for Creole Petroleum Corporation for use at Lake Maracaibo, Venezuela.

The barge is 70 ft wide and 175 ft long, and the main power plant for drilling is made up of three 400-kw D.C. generators. Four 75-kw auxiliary generators supply power for lighting, etc. For the rig itself there are three 500-h.p. motors for mud pumps, one 800-h.p. unit for hoisting, one 300-h.p. for the rotary table, and a 60-h.p. motor for mud mixing, a total of 2660 h.p.

U.K. PETROLEUM TRADE IN 1948

By GEORGE SELL (Fellow)

IMPORTS of crude petroleum into the United Kingdom during 1948 totalled 1,174,663,000 gallons, an increase of 558,816,000 gallons (90·7 per cent) over the 1947 total and the highest annual import yet recorded.

In the case of refined products the total import in 1948—3,499,018,000 gallons—was 655,088,000 gallons, or 23 per cent higher than in the previous year. The only product to show a reduced import in relation to 1947 was motor spirit, but only to the extent of 0·2 per cent. The import of 408,399,000 gallons of kerosine in 1948 was the highest ever recorded, the previous record being 401,427,000 gallons in 1946. The total of 1,303,593,000 gallons for fuel and diesel oils in 1948 is about 65 per cent higher than in 1947 and has only been exceeded once before—in 1944 when the figure was 1,334,934,000.

It is of interest to note that in 1948 and in 1947 the imports of crude petroleum represented 17·7 and 17·8 per cent respectively of the grand total of crude and refined products. However, in 1948 there was a material change and the percentages were 25·2 per cent for crude petroleum and 74·8 per cent for refined products. In the case of the individual products there have been considerable changes in the percentage imports in the post-war period as compared with 1938, the last pre-war full year. Details are given in Table I.

TABLE I

PERCENTAGE IMPORTS OF PETROLEUM PRODUCTS

	1948	1947	1946	1938
	Per cent			
Motor spirit	34·1	42·1	36·9	55·3
Other spirit	0·9	0·8	0·9	0·7
Kerosine	11·7	11·4	12·3	7·8
Lubricating oil	2·5	3·0	2·7	4·1
Gas oil	13·6	14·9	15·0	6·0
Fuel and diesel oils	37·2	27·8	32·2	26·1
	100·0	100·0	100·0	100·0

TABLE II

QUANTITY AND VALUE OF U.K. PETROLEUM IMPORTS

	1948		1947		1938	
	Quantity 1000 *gal*	*Value* £	*Quantity* 1000 *gal*	*Value* £	*Quantity* 1000 *gal*	*Value* £
Crude petroleum	1,174,663	31,079,960	615,847	13,143,461	567,953	5,177,532
Motor spirit	1,193,943	47,118,761	1,196,556	38,427,953	1,456,667	24,764 928
Other spirit	30,118	1,389,812	23,901	868,775	18,097	310,582
Kerosine	408,399	15,028,249	325,440	9,522,566	206,362	3,004,476
Lubricating oil	86,419	7,865,642	85,086	6,770,081	108,198	3,953,811
Gas oil	476,468	17,381,410	423,366	11,571,146	157,926	2,125,615
Fuel and diesel oils	1,303,593	35,547,084	789,567	18,227,589	687,346	6,570,470
Other sorts	78	29,934	14	5,140	956	72,783
Total refined products	3,499,018	£124,360,892	2,843,930	£85,393,250	2,635,552	£40,802,665
GRAND TOTAL	4,673,681	£155,440,852	3,459,777	£98,536,711	3,203,505	£45,980,197
	Cwt		*Cwt*		*Cwt*	
Paraffin wax	720,290	2,314,185	766,372	2,307,743	809,749	635,036
Mineral jelly	195,373	328,341	196,220	338,184	136,378	155,731
Carbon black from natural gas	874,815	2,700,120	757,193	2,182,392	386,208	512,754
	Tons		*Tons*		*Tons*	
Natural asphalt and bitumen	44,630	448,879	30,855	352,943	79,164	290,944

TABLE III

AVERAGE UNIT VALUES OF U.K. PETROLEUM IMPORTS

	1948	1947	1938
	£ *per* 1000 *gal*		
Crude petroleum	26·46	21·34	9·12
Motor spirit	39·46	32·11	17·00
Other spirit	46·15	36·35	17·16
Kerosine	36·80	29·26	14·56
Lubricating oil	91·02	79·57	35·54
Gas oil	36·48	27·33	13·46
Fuel and diesel oils	27·27	23·09	9·56
Other sorts	383·77	367·14	76·13
Total refined products	35·54	30·03	15·48
	£ *per cent*		
Paraffin wax	3·21	3·01	0·78
Mineral jelly	1·68	1·72	0·14
Carbon black	3·09	2·88	1·33
	£ *per ton*		
Natural asphalt and bitumen	10·06	11·44	3·68

Details from the official return* are given in Table II, and from this it will be seen that the total value of crude and refined products imported in 1948 was 57·7 per cent higher than in 1947, while the aggregate value of the refined products was 45·6 per cent higher. In Table III the c.i.f. values have been calculated on a unit basis and it will be seen that for the refined products the figures show increases of from 14·4 per cent for lubricating oil to 33·5 per cent for gas oil. Crude oil value was 24 per cent higher in 1948 than in 1947.

Consigning Countries

In Table IV the details which are available as to consigning countries have been analysed, but it must be borne in mind that a "consigning" country is not necessarily the country of origin of the product imported.

Total imports of crude and refined

TABLE IV

COUNTRIES CONSIGNING PETROLEUM TO THE U.K.

Country and Product	1948	1947	1938
	Thousand gallons		
British West Indies:			
Motor spirit	89,685	102,969	90,607
Kerosine	45,883	57,717	—
Fuel & diesel oils	70,532	73,616	118,136
	206,100	234,302	208,743
Bahrein, Kuwait, Qatar, & Trucial Oman:			
Crude petroleum	156,973	43,854	—
Motor spirit	21,128	33,218	—
Kerosine	19,565	22,056	—
	197,666	99,128	—
Palestine:			
Motor spirit	13,413	25,281	—
Other British:			
Crude petroleum	23,101	19	20,390
Motor spirit	73	1	8,022
Kerosine	—	1	2,854
Lubricating oil	78	110	79
Gas oil	39,465	25,529	12,039
Fuel & diesel oils	16,585	11,619	1,197
	79,302	37,279	44,581
Netherlands West Indies:			
Crude petroleum	277,865	221,534	160,782
Motor spirit	505,128	413,733	589,531
Kerosine	205,897	139,177	50,892
Lubricating oil	7,304	18,497	—
Gas oil	113,463	84,490	21,936
Fuel & diesel oils	722,011	368,456	251,290
	1,831,668	1,245,887	1,074,431
Iran:			
Crude petroleum	247,386	154,883	54,221
Motor spirit	214,420	68,054	314,066
Kerosine	134,796	50,048	59,884
Gas oil	99,341	20,520	37,093
Fuel & diesel oils	425,077	283,475	161,365
	1,121,020	576,980	626,629
United States:			
Crude petroleum	16,488	10,829	14,995
Motor spirit	284,266	483,543	314,497
Kerosine	1,930	51,507	57,800
Lubricating oil	79,024	66,223	85,660
Gas oil	157,525	241,112	39,404
Fuel & diesel oils	11,837	31,319	63,312
	551,070	884,533	575,668
Saudi Arabia:			
Crude petroleum	176,900	60,561	—
Iraq:			
Crude petroleum	145,213	—	141,796
Venezuela:			
Crude petroleum	58,213	100,947	138,975
Motor spirit	17,218	37,542	—
Gas oil	13,767	47,919	—
Fuel & diesel oils	9,493	12,247	13,860
	98,691	198,655	152,835
Peru:			
Crude petroleum	40,063	23,220	21,865
Soviet Union:			
Motor spirit	9,173	12,838	47,460
Lubricating oil	—	—	13,360
	9,173	12,838	60,820
Netherlands East Indies:			
Motor spirit	—	—	23,854
Other Foreign:			
Crude petroleum	32,461	—	14,929
Motor spirit	39,439	19,377	68,630
Kerosine	328	4,934	34,932
Lubricating oil	13	256	9,099
Gas oil	52,907	3,796	47,454
Fuel & diesel oils	48,058	8,835	78,186
	173,206	37,198	253,230

* "Accounts relating to trade and navigation of the United Kingdom, December 1948."

products from British countries in 1948 amounted to 496,481,000 gallons (10·6 *per cent of grand total*), in 1947 to 395,990,000 gallons (11·4 *per cent*) and in 1938 to 253,324,000 gallons (0·8 *per cent*). A new entry under British countries is the group Bahrein, Kuwait, Qatar, and Trucial Oman. The details now disclosed in respect of 1947 were previously entered under the heading of "Other British". It is unfortunate that comparatively large quantities of gas, fuel, and diesel oils are still given under the latter heading without disclosing the country of consignment.

In the foreign countries it is noteworthy that Iran has now replaced the U.S.A. as second in the list as regards total exports to the U.K. with nearly double the quantity in 1948 in comparison with 1947. The only new country in the foreign list is Saudi Arabia, and it is important to note that the crude oil imported therefrom in 1948 was nearly treble the 1947 quantity. Nearly one-third of the total imports for 1948 are included as coming from "other foreign" countries.

Re-Exports

Total re-exports of imported oils in 1948 amounted to less than half the quantity re-exported in 1947. Details are given in Table V.

TABLE V

U.K. RE-EXPORTS OF IMPORTED PETROLEUM

	1948	1947	1938
	Thousand gallons		
Motor spirit	13,191	40,600	14,075
Kerosine	2,104	3,373	2,832
Lubricating oil	1,636	3,831	4,344
Fuel & diesel oils	21,860	40,166	4,284
All other sorts	2,709	3,852	3,596
Total	41,500	91,822	29,131
Value	£1,678,372	£3,108,248	£800,496
Oil fuel for use in steamers	458,048	461,961	313,204

The quantity of fuel oil shipped for the use of steamers engaged in the foreign trade (including fishing vessels) was the highest ever recorded.

Exports

Details of the export of petroleum products produced or manufactured in the United Kingdom are given in Table VI. The total at 45,996,000 gallons was only 59·9 per cent of the 1947 total, although the total value showed an increase of 10·3 per cent. Comparative values of individual products in £ per 1,000 gallons are: motor spirit, £46·09 (£36·19 *in* 1947); lubricating oil, £161·91 (£126·06); gas oil, £36·21 (£25·19); fuel and diesel oils, £31·35 (£22·71); all other sorts, £99·63 (£76·41). The latter designation now includes kerosine.

TABLE VI

U.K. EXPORTS OF HOME-PRODUCED AND HOME-MANUFACTURED PETROLEUM

	1948		1947		1938	
	Quantity 1000 *gal*	*Value* £	*Quantity* 1000 *gal*	*Value* £	*Quantity* 1000 *gal*	*Value* £
Motor spirit	5,962	274,793	23,502	850,533	54,982	884,969
Lubricating oil	27,956	4,526,482	28,492	3,591,841	17,466	1,161,520
Gas oil	4,246	153,765	11,730	295,478	29,129	384,434
Fuel and diesel oils	5,627	176,404	10,921	247,974	17,200	178,341
All other sorts	2,205	219,690	2,195	167,719	14,904	244,673
TOTAL	45,996	£5,351,134	76,840	£5,153,545	133,681	£2,853,937
	Cwt		*Cwt*		*Cwt*	
Lubricating compounds	131,994	435,446	95,702	315,010	605,265	714,364
Paraffin wax	53,093	208,794	70,710	273,768	88,016	75,911
	Tons		*Tons*		*Tons*	
Manufactured bituminous asphalt and emuslions	74,065	951,199	47,860	591,559	91,928	426,059

COLLOIDAL FUEL

By R. A. ACTON TAYLOR*

Introduction

Colloidal fuel[1] is a suspension of pulverized coal in fuel oil and is a fuel that might be used, for example, under boilers and in metallurgical furnaces fitted with suitably adapted oil-burning equipment. It occupies a strange position. It was patented in America as long ago as 1879,[2] and received only occasional attention until during the war of 1914 to 1918, since when it has commanded a fluctuating but nevertheless widespread and sustained interest, and has been the subject of much experimental work and of careful consideration in the economic field. Technical difficulties in preparing and using it have been overcome, and the adaptation of much existing oil-burning equipment, where its use would be appropriate, would be slight; and conditions in which it could be used economically have occurred. Nevertheless, in spite of extensive trials, it has never come into use. The reason for this is not clear.

The term colloidal fuel is a misnomer, but is established by usage, even internationally, and thus has, as these things go in the English language, an unassailable claim to acceptance. It is idle, therefore, to pursue the controversy about the name; none of the suggested alternatives, reasonable or pedantic, has become generally recognized.

The Raison d'Être of Colloidal Fuel

Colloidal fuel affords a means of eking out valuable supplies of oil by the substitution of coal. Thus, if colloidal fuel had been burnt instead of boiler fuel oil in the British mercantile marine and the fishing fleets alone—coastwise traders excluded—in 1947, the importation of six hundred thousand tons of oil would have been saved.

The stress of war has always stimulated interest in colloidal fuel. Thus, in America, the "Submarine Defense Association" was formed in 1917 to consider in detail the possibilities of colloidal fuel;[3] and in the early nineteen-forties a scheme was evolved by the Petroleum Administration for War for setting up a coast-to-coast chain of stations for the production and distribution of colloidal fuel.[4] In Britain the possibilities were continually under review[1(d)] and in 1940 were investigated by the Geddes Committee appointed by the Mines Department (now the Ministry of Fuel and Power).

The Properties of Colloidal Fuel

Colloidal fuel combines some of the respective advantages of coal and oil, and generally its properties are what would be expected from those of its constituents. Coal is the cheaper fuel; oil is more easily handled and more flexible in control and operation. The thermal density of colloidal fuel, that is, the calorific value on a volume basis, is greater than that of any other fuel, an important consideration when storage space, as in a ship's bunkers, is valuable.

There is one respect in which the properties of the mixture cannot so easily be predicted, and that must be satisfactory above all others: the suspension must be stable. The fuel must be economic, and this means that the cost of preparing it, due mostly to pulverizing the coal and mixing it with the oil, must not be too high.

It has been shown that the coal in colloidal fuel, which is universally and

* Fuel Research Station, Department of Scientific and Industrial Research.

tacitly accepted as being made with petroleum oil, can be recovered unchanged.[5] This shows the mixture to be a mechanical suspension. Occasionally, tar oil of one kind or another has been suggested or tried mixed with pulverized coal,[6] and in such a mixture the coal is undoubtedly partly dissolved or peptized. Despite much speculation, which is ill-founded, there is no question of this happening in ordinary colloidal fuel.

Stability

Generally, when a finely-divided solid material is suspended in a specifically lighter liquid it will separate by sinking. A colloidal fuel is of no use if the coal settles too quickly, for it will cause troublesome deposits and blockages in handling equipment. This must be considered in connexion with the maximum temperature at which the fuel will be stored or handled.

The rate of sedimentation is affected by several factors, for example:

(*a*) *the difference in specific gravity between the coal and the oil is fixed, and cannot be controlled to favour stability;*

(*b*) *the viscosity of the oil varies from one oil to another, and could be favourably influenced by adding substances that "thicken" the oil;*

(*c*) *the finer the coal the more slowly it separates;*

(*d*) *a rise in temperature rapidly decreases the viscosity of the oil; storage and handling temperatures must therefore be as low as possible;*

(*e*) *the shape of the particles of coal; the more a suspended particle departs in shape from a sphere, the more slowly it falls; the physical structure of the coal and the method of grinding might be chosen to favour stability; these factors, which might contribute to stability, seem never to have been investigated.*

It should be added that, properly speaking, stability means no sedimentation at all, a condition that it is practically impossible to achieve; but a rate of sedimentation slow enough to be tolerable is accepted as "stability".

The viscosity of the oil

The course of investigations on the achievement of stability was very different in Britain from what it was in America. An oil that is very viscous may still not give a suspension stable enough for practical purposes. In Britain it was observed that certain fuel oils were not true or Newtonian liquids; they had "consistency" or were thixotropic, or in some way showed the property of being resistant to the small force exerted by a coal particle sinking in them, while yet flowing relatively freely under larger forces, such as when they were poured or pumped.[7] A survey of the oil market showed that there was a reliable supply of a small number of oils of this kind, ensuring for some time to come a source of oils suitable for making colloidal fuel.

In America, oils were at first made suitable by the addition to them of something imparting "consistency", or whatever property it is that produces the desired result. Very many patents have been granted to cover the addition of soaps, rubber, resin, pitch, bitumen, waxes and greases, and so on. Such substances, called "stabilizers" in Britain, are referred to in American literature as "fixateurs". They were considered very fully in Britain, but several practical difficulties were apparent:

(*a*) *the stabilizer must be reliable in the amounts used, and its effect must be durable;*

(*b*) *a source of it must be assured;*

(*c*) *the amount of the stabilizer required would depend on its effectiveness and must be considered in*

conjunction with its price per pound;

(*d*) *the cost of the stabilizer, it was estimated, must not exceed about half a crown per ton of colloidal fuel;*

(*e*) *it must be easy to incorporate into the oil.*

Since 1 per cent of a stabilizer in the colloidal fuel means that its price must be about a penny a pound, clearly it must be effective in minute percentages or it must be a waste product. There probably is no waste product that complies with all the requirements. Of other substances, ordinary soap in the form of sodium stearate seemed promising; only 0·25 per cent of it can be made to give a dilute gel that scarcely effects the pumpability of the mixture and yet opposes ample rigidity to the small force exerted by a sinking particle. But the pre-war price of sodium stearate was greater than could be tolerated; furteer, an inconveniently high temperature was necessary to dissolve it in the oil; and finally its effect was not enduring, for the gel slowly broke and separated into two phases. No practical way of overcoming this difficulty was found.

The economic problem of stabilizers has thus not been solved. This view seems now to be shared in America, where consideration has turned to oils that are intrinsically suitable.[1(b)]

The assessment and criteria of stability

There was for a long time no satisfactory or standard method of determining the stability of colloidal fuel, nor of expressing it in a single characteristic. Eventually, however, a simple method evolved was to investigate the behaviour of the specimen in a test-tube arranged so that it could oscillate like a pendulum; the period of the pendulum enabled the amount by which the coal, as a whole, sunk to be calculated from the change in the position of the centre of gravity. The specimen could be evaluated while yet being preserved intact; the method was sensitive enough to show in a few days a rate of sedimentation that might not be observed in months by other methods.

Experience with colloidal fuels in practice and the examination of them by this method led to the establishment of a provisional criterion that an oil was satisfactory if the coal did not sink in it at a rate exceeding 0·07 mm per day at 25° C. Roughly speaking, this means that a non-fluid sludge a millimetre deep will be deposited in a week.

The proportions of a colloidal fuel

In the nature of things, the more coal a colloidal fuel contains the more it justifies itself. Further, the rate of sedimentation is decreased when the coal content is increased. However, there is an upper limit to the content of coal because the mixture increases in consistency with the percentage of coal until it is too thick to handle conveniently or to pump economically.

From experience, about 40 parts of coal to 60 parts of oil was accepted in Britain, and apparently in America, too, to represent a working standard for all oils, and has met with wide tacit acceptance.

Up to 55 per cent of coal has been claimed, although such mixtures may not always have been produced with all the requirements in view; on the other hand, some oils could carry more coal than others. But it is much more convenient, at least in the pioneering work, to determine a value that is applicable to all oils, even if in practice the percentage of coal can in individual instances be increased.

The size of the coal

Pulverized fuel is produced on a very large scale in standard, well developed plant distributed throughout the U.K., and an approximate grading generally accepted for such fuel is 95 per cent through a 120 B.S. sieve and 80 per cent through a 240 B.S. sieve. It is only to be

expected therefore that one would at least start with pulverized fuel to make colloidal fuel.

The finer the coal is, the more stable will be a colloidal fuel made with it; but whereas the cost of producing pulverized coal, for which there is a great demand, is economic, the cost increases disproportionately as the coal is made finer. This is partly because there is no demand for finer coal and so there is very little plant for producing it; and what there is, is of very small capacity; but it is also due to the much greater difficulty of producing, classifying, and handling finer coal, and the disproportionate increase in power needed and the decrease in throughput of a plant of given size, and these factors, as affecting the price, are largely independent of the demand. Coals of finer grading than ordinary pulverized fuel have sometimes been used, though never on any but a small scale, and have often been advocated with no appreciation of the difficulties entailed. As a relatively important increase in fineness is necessary to produce a useful increase in stability, there is little to gain unless there is a radical change in the economic and quantitative prospects of pulverizing the coal much finer than ordinary pulverized fuel. However, it is not impossible that newer pulverizing techniques may fulfil requirements. Thus, a high-velocity steam jet carrying coal, subjected to the transverse action of high-velocity gas jets causing impaction on surfaces and disintegration of the coal,[8] or the sudden expansion of a high-pressure gas-stream carrying coal causing disruption of the coal,[9] are being tried.

Equipment for Burning Colloidal Fuel

Generally, as has been indicated, equipment for handling and burning oil needs little adaptation for burning colloidal fuel.

The first concern, however, is with the furnace. The replacement of oil by colloidal fuel means the introduction of ash into a combustion space where there was none before, and the use of colloidal fuel can only be entertained when this does not matter. Thus, bird-nesting or other deposits in narrow passages may occur in a water-tube boiler designed to burn oil in a small combustion space with a high rate of heat-release; or material in a metallurgical furnace, for example, may be damaged by fly-ash. In such circumstances, nothing short of redesigning the furnace will serve, and this is usually impracticable or uneconomic. The range of furnaces in which colloidal fuel could be burnt would be increased if the coal in the colloidal fuel were selected to have a low percentage of ash with a high fusion temperature.

There will always be a certain amount of sludge deposited in a colloidal-fuel storage tank, even if no one filling of the tank remains in it long, so that slow stirring at the bottom of the tank, or circulation through it, is an advantage.

As colloidal fuel is much more viscous than oil fuel, it is necessary to ensure that the capacity of pumps is adequate. Further, the leads to burners may need heating jackets where there were none before, or they may need stronger preheating than was applied before. The preheating of the air for combustion may also be an advantage.

Although standard types of oil burners are more or less suitable, larger atomizing jets than those used for oil have been found advantageous. Again, as colloidal fuel is abrasive compared with oil, the wear on the burner jets is relatively great. Investigations into a suitable material for the jets have been projected, and it will probably not be difficult to find a suitable alloy for them; as it is, they need not be so expensive that their more frequent replacement is serious.

Other modifications to the burning equipment, the air supplies and the furnace itself, depending on the details in the design and arrangement of the

plant as a whole, are best dealt with as the need arises. Thus, ignition and combustion may be facilitated by a zone of refractory brick built in the front end of the furnace; and a tertiary air-supply, preheated or not as required, may be found desirable.

The literature of colloidal fuel often appears out of balance in that the space devoted to the use of the mixture is small compared with that devoted to making it. This may seem surprising to the engineer who is primarily concerned with using the fuel, but in fact it represents the relative magnitudes of the two sides—the production and the use: the making of stable and otherwise satisfactory mixtures is a serious problem, well understood but not so easy to solve technically and economically—but it must be achieved reliably; on the other hand, there is no fundamental difficulty in burning the fuel, although experience shows the need for miscellaneous individually minor adaptations of and improvements to existing equipment.

The field for colloidal fuel

During the course of years a variety of authorities with diverse interests have undertaken tests on colloidal fuel, so that the application of it in trials covers a range of types of furnaces. All these tests seem to have satisfied their sponsors and any reservations seem to be of a minor nature. The following is a representative but not exhaustive list of such tests:

(*a*) 1917–1918: *sea trials under naval service conditions and land trials by the Submarine Defense Association in America*[3];

(*b*) 1922: *trials in a locomotive of the Great Central Railway by J. G. Robinson*[10];

(*c*) 1932: *trials of the S.S.* Scythia *by the Cunard Steamship Co. Ltd.*[11];

(*d*) 1932: *trials in a single furnace-tube (Cornish type) boiler by the Maschinenbau A-G Balcke (Ruhr); in this work, however, tar oil was used.* Cf *W. Schultes*[6];

(*e*) 1935: *trials on a vertical cross-tube boiler at Cardiff*[12];

(*f*) 1938–1939: *trials on a land-installed marine boiler and on an industrial (re-heating or annealing) furnace by the Mines Department (unpublished);*

(*g*) 1940: *a further trial at sea, due to the Mines Department's Geddes Committee (unpublished);*

(*h*) 1942: *trials on a Babcock and Wilcox water-tube boiler by U.S. Bureau of Mines and Atlantic Refining Co.*[15] Cf *also A. Burcher (contribution to discussion reference 1b).*

Such a compilation of data provides a great fund of information on what is to be expected of colloidal fuel in use.

As to efficiency, parallel trials on colloidal fuel and on its oil alone have shown efficiencies with colloidal fuel to be only slightly lower than those with the oil; and there was no perceptible difference in flexibility of operation ((*f*) above).

Colloidal fuel could be used in certain types of ships' boiler furnaces, especially in the fishing-fleets and in cargo vessels, possibly in certain types of liners, but not in naval vessels, whose boiler furnaces are designed exclusively for oil fuel; in liners it would have to be ensured that fly-ash and particles of incompletely burnt coal would not be a nuisance to passengers. It has a field also for use in many types of land installations, under boilers, in central heating plants, and in many furnaces in metallurgical and other industries.

A sharp distinction has been drawn between the possibilities at sea and on land, because instability would cause more serious difficulties in ships' installations than in land works; but in view of the very promising trials that have been carried out at sea, the distinction has probably been exaggerated.

Ships would generally have to be bunkered from colloidal fuel stocks prepared in land installations; on land the larger consumers could prepare their own mixtures, and the smaller ones could draw their supplies from central plant specially built to prepare it for distribution. Suitable and economic unit plant of quite small capacity would probably soon be developed, however, if colloidal fuel were to establish itself on a practical scale, and the range of consumers who made their own would be extended to include many otherwise classed as "small consumers". This is an important consideration, because the Geddes Committee, investigating land markets, found that much of the fuel would have had to be distributed among a number of scattered small consumers, though they tended to be concentrated in London, Birmingham, and a few other large urban areas. The Geddes Committee, however, concluded that central production was necessary, and advanced a long way with plans for a pilot industrial plant for central production; but they foresaw that distribution costs would constitute an economic item that had up to then scarcely been considered.

It is likely that this work of the Geddes Committee would have led to the production, distribution and use of colloidal fuel on an extensive scale that would have either established or disposed of colloidal fuel once and for all, had it not been that the fuel was forestalled, in the market envisaged for it, by creosote-pitch mixtures, which, as a temporary expedient, could be produced and distributed much more readily, and, in the abnormal economic circumstances prevailing, more economically and with less capital outlay. The result is that, as a fuel for use where it is appropriate, colloidal fuel has never had an extensive trial to provide the long-term experience that alone would one way or another put an end to its lingering existence in a state of arrested development.

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(1) (*a*) A. B. Manning and R. A. Acton Taylor: "Colloidal fuel," *Trans. Inst. Chem. Eng.*, 1936, **14**, 45–53; (*b*) W. C. Schroeder: "Use of mixtures of oil and coal in boiler furnaces," *Mech. Engineering*, 1942, **64**, 793–798, 804; the discussion of this latter paper raises many interesting questions.

(2) H. Smith and H. Munsell: U.S. Pat. 219, 181 (2.xi.79).

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(4) Petroleum Administration for War, Marketing Division: "Colloidal fuel program," 1942, pp. 33.

(5) Fuel Research Board, "Report for year ending 31st March, 1935," p. 153.

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(10) *Modern Transport*, 1922, **7**, 3.

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(12) *Cf.* S. L. Wyndham: Brit. Pat. 410,883 (1934).

(13) J. F. Barkley, A. B. Hersberger and L. R. Burdick: "Laboratory and field tests on coal-in-oil fuels," *Trans. Amer. Soc. Mech. Eng.*, 1944, **66**, 185–198; other references to the same work are: *Coal Age*, 1943, **48**, 51–53; *Nat. Petr. News*, 1943, **35**, R304–306; *Steel*, July 12, 1943.

SCOTTISH BRANCH

A MEETING of the Scottish Branch, attended by nearly seventy members and friends, was held on January 14, 1949, in the North British Station Hotel, Edinburgh, the chair being taken by Mr Robert Crichton. Dr C. E. Foister, B.A., Dipl. Agr. Sci., Plant Pathologist of the Department of Agriculture for Scotland, gave a lecture on "The Economic Background of Plant Protection and the Uses of Petroleum Products".

Dr Foister gave some examples of serious losses of various crops caused by diseases and insect pests in the U.K. and in the U.S.A. The difficulties of assessing monetary loss occasioned by diseases and pests were discussed and some empirical estimates of such losses in Scotland were presented. The agricultural and horticultural crops in Scotland are valued officially at over £20 million, though some have estimated a value of over twice this figure. The speaker thought that if accurate measurements were made over a period of years by specialists the aggregate loss caused by all our diseases and insects and other pests might easily be found to reach 25 per cent of the theoretical peak production. However, even taking a very conservative estimate of 10 per cent loss, excluding that due to rodents and birds, the annual loss would be £2 million.

The causes of disease and the kinds of pests involved were outlined, involving fungi, bacteria, viruses, helminths, insects and mites, though pests such as birds and rabbits also cause annually enormous losses.

The principles of plant protection were discussed, most attention being given to chemical methods; the uses of chemicals as dusts, sprays, rapid and slowly volatilizing fumigants, and their action as protective, destructive and toxic agents were described, with examples of the diseases or insects they control. A reasonably comprehensive list of chemicals used in plant protection was presented. The problems involved in the use of these products were dealt with, such as their specificity to certain diseases or pests, their toxicity to plants at certain stages of growth, the effect of weather or locality or variety of crop on their efficacy or toxicity to the plant, and the secondary reasons for their use. In the latter case, it may be more important to control insects which transmit virus diseases to secure virus-free crops than for any damage the insect may cause, independent of viruses they transmit. Also one treatment may effect a double purpose: for example, arsenical sprays were used in France to control Colorado beetle, but now a combined arsenical and bordeaux mixture spray is given to control both beetle and potato blight, the control of the latter being judged to be more important. Without Colorado beetle, blight spraying, nevertheless, would be neglected. Reasons were given for the more diverse chemical control methods in horticulture than in agriculture. In connexion with the fuller treatment of the use of petroleum and allied sprays in fruit orchards, a comparison was made between the history of fruit protection in U.S.A., the Dominions, Kent, and the Clyde Valley; neglect of pest and disease control was connected with lack of capital for purchase of spray machinery without which, however, yields and quality of fruit remained poor. Only when the vicious circle was broken could the fruit industry be put on its feet. The tar-distillate, and winter and summer petroleum washes, combination sprays and the newer Dinitro-ortho-cresol-petroleum sprays were dealt with in some detail, the limitations of each being indicated, along with the pests involved, such as fruit-tree red spider, the winter moth group, apple sawfly, and greenflies.

Some methods of dealing with agricultural diseases such as potato dry rot, and seed-borne diseases were dealt with briefly. The Government's scheme for approval of proprietary products for the control of plant pests and diseases was

described, over 250 products having been approved in some 38 groups. The speaker finally referred to the inter-relationship of the research stations, the insecticide and fungicide manufacturing trade, and the national advisory services in England and in Scotland, without which the remarkable advances in this subject could not have resulted.

The lecture was illustrated by many lantern slides and was followed by an interesting discussion. A vote of thanks to Dr Foister (proposed by Professor Nisbet) and a vote of thanks to the Chairman (proposed by Dr William Reid) were received with acclamation.

Preceding the lecture the Annual General Meeting of the section was held. Vacancies in the committee were filled by the election of Mr Robert Crichton, Dr G. H. Smith, Messrs A. Fleming, J. T. Guthrie, Hector McArthur, Dr William Reid, Mr William Stirling and Professor H. B. Nisbet.

STANLOW BRANCH

STANLOW Branch held its annual general meeting on January 19, 1949.

In his report, the Chairman briefly reviewed the principal Branch activities during the past year and drew attention to the steady increase in the size of the Branch which, at January 1, 1949, numbered 161 (91 of the members being corporate members of the parent body).

During the year 1948 the policy of holding joint meetings in Chester with the local sections of the Royal Institute of Chemistry and the Society of Chemical Industry, had been brought into effect, one such meeting having been held and two more being scheduled for the remainder of the 1948/49 session.

Three members of the committee, Mr J. G. Hancock (*Hon. Secretary*), Dr N. Kendall and Mr F. Mackley (the last two named being members co-opted during the year to fill vacancies) were due for retirement, but eligible for re-election and, no other nominations having been received, they were duly declared elected.

The accounts of the Branch were presented by the Hon. Treasurer and showed a favourable balance of £36 on the year. The two Hon. Auditors, Messrs Don and Tripp, were re-elected for 1949.

The Chairman asked members to express any views they might have regarding the type of paper which they would like to see presented at meetings of the Branch and the opinion was voiced that there should be more papers dealing with actual refining procedures, with perhaps a lesser emphasis than hitherto on purely research aspects of petroleum technology. It was also suggested that papers on the actual applications of products would be very welcome.

At the conclusion of the formal business of the meeting the Chairman introduced Lt-Col S. J. M. Auld, O.B.E., M.C., a Past-President of the Institute, who gave a very stimulating address. The lecturer's theme was the implications of the expansion of the oil refining industry in the United Kingdom and the role that the Institute of Petroleum could play in these developments. He pointed out that in a presidential address that he gave to the Institution of Petroleum Technologists (as it then was) over ten years ago (see *J. Inst. Petrol Techn.*, 1938, **24**, 243), he had previously dealt with the position held by the Institute and the scope of its activities, and he took the present opportunity of drawing the attention of his audience to the very considerable developments that had been made since that date.

The three main causes of the present temporary shortage of petroleum products were the slackening off in the rate of production, the lack of refining capacity due to war-time destruction and cessation of building, and the large increase in the use of oil. Stress was laid on the rapid expansion of the Middle

East oil area and the opportunities that this gave for the United Kingdom to assume leadership in the development of the petroleum refining industry of Europe. At present the U.K. was a long way behind the United States in "oil-consciousness", and it should be the task of the Institute of Petroleum to emphasize the importance of the petroleum refining industry as a vital factor in the nation's economic revival.

The importance of the petroleum refining industry of Great Britain was insufficiently realized by the average citizen. Within the next five years or so an extremely rapid expansion was due to occur and the refining and export of petroleum products would become one of the major industrial activities of the country.

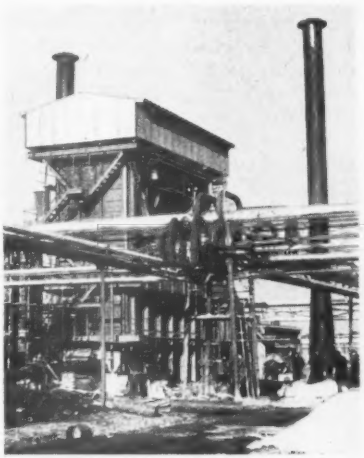
The Institute, through its publications and other activities, should be a natural source of authoritative information on oil matters for both Government departments and the nation as a whole. The branches of the Institute had an important part to play in such activities and provided the benefits of decentralization, whereby the wide variety of members' interests could be catered for. Every effort should be made by the branches to attract the junior members of the oil industry, and it must be remembered that "every office boy has a managing director's fountain pen tucked away somewhere in his pocket".

At the conclusion of the lecture there was a brief discussion, and the meeting concluded with a vote of thanks proposed by Mr J. S. Parker.

VENEZUELAN PIPELINE

The completion of a 146-mile pipeline from Ulé to the company's refinery on the eastern shores of Lake Maracaibo and its ocean terminal at Amuay Bay is announced by Creole Petroleum Corpn. There are two pumping stations, at Ulé and at Dabajuro, and full capacity of the line is 300,000 to 325,000 barrels daily.

CATAROLE PLANT IN OPERATION



Petrochemicals Ltd. have announced that they have started up the first cracking furnace (seen above) of their chemicals-from-petroleum plant at Partington, near Manchester. This plant employs the Catarole process, and the unit is reported to be working satisfactorily at a rate in excess of nominal capacity.

"WATER SUPPLY AND GEOLOGY"

Last year's Abbott Memorial Lecture to the University of Nottingham was delivered by Professor H. G. A. Hickling, D.Sc., F.R.S., who chose the above for his subject. He discusses the problem of water supply in Great Britain and concludes with two pleas. The first is for more unprejudiced public consideration regarding reservoir schemes, and the second is that sewage and industrial waste be restored to a clean and innocuous condition before discharge into rivers from which water supplies will have to be drawn. Copies of the lecture are available from the University, Nottingham, price 1*s.* 6*d.*

PETROLEUM IN PALESTINE

THE presence or absence of oil in Palestine has not so far been subjected to any extent to the final test of drilling, although such tests have been started by the holders of oil prospecting licences since the end of the war, said S. H. Shaw (*Geologist, Government of Palestine*) in a lecture* at the Imperial Institute, London, in October 1947.

Interest in oil prospecting in Palestine is centred around three main areas: (*a*) the coastal plain; (*b*) the Negev; and (*c*) the southern end of the Dead Sea.

In the coastal plain, geophysical work has been carried out and a trial well was being drilled by Petroleum Development (Palestine) Ltd. at Huligat, north of Gaza. A matter of considerable interest was in determining whether a full series of Miocene and Oligocene formations was present beneath the younger Tertiaries.

The numerous anticlinal structures in the Negev are potentially oil-bearing, but are so deeply eroded that any reservoir rock must in general be of pre-Jurassic age. The presence of igneous intrusions is also an unfavourable feature. Although the discovery of oil at Ras Gharib in Egypt in Carboniferous beds does not rule out the possibility of oil being found in Palestine in beds older than the Jurassic, the prospects are problematical as far as structures in the southern part of the country are concerned.

The area of the southern end of the Dead Sea contains the only direct indications of the presence of oil, and the salt mountain of Jebel Usdum is significant. The salt is associated with sediments which may well be of Miocene age. Although the presence of this mountain suggests suitable structural traps for the accumulation of oil, the faulted nature of the area leaves uncertainty as to whether the faulting movements may not have dissipated rather than have conserved oil. Several bores to obtain geological information have been made.

BITUMEN

Solid bitumen of great purity is often found floating in the Dead Sea, and has presumably been forced to the surface through fissures. It bears a considerable resemblance to the bitumen occurring in veins in Senonian chalks of Hesbaya, in Syria.

Viscous, liquid bitumen occurs in small seepages at Masada and Wadi Mahawit towards the south-western end of the Dead Sea, apparently being derived from Cenomanian strata. At the latter place, wadi gravels are impregnated with bitumen and oil-impregnated sand is known south of Jebel Usdum. Small occurrences are also found on the Trans-Jordan side of the Dead Sea. None is of commercial value, but they are of interest in connexion with the possible occurrence of oil.

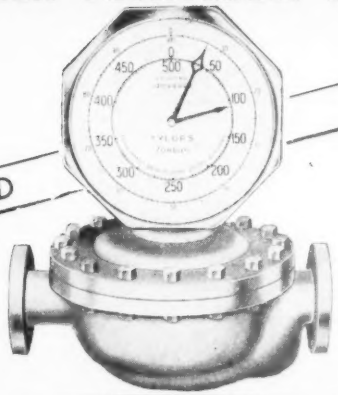
BITUMINOUS LIMESTONE

Bituminous limestone and marls are widespread in the Campanian-Maestrichtian. By destructive distillation they may yield up to 12 per cent oil, but the oil is so poor in quality that so far no means of making commercial use of this rock have been found. The principal areas where high-grade bituminous limestone occurs are near Nabi Musa, south of the Jerusalem–Jericho road, and in the Yârmuk Valley.

Eye-protective Glasses.—National Bureau of Standards Circular C.471, "Spectral transmissive properties and use of eye-protective glasses", is a study of about 200 glasses intended for use as sun glasses or in special industrial operations. The publication is obtainable from the Supt. of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A., at 20 cents per copy.

* "The geology and mineral resources of Palestine," *Bull. Imp. Inst.*, 1948, **46** (1), 87–103.

VOLUMETERS FOR OIL, PETROL AND OTHER PETROLEUM PRODUCTS



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PERSONAL NOTES

Hugh C. Tett, F.Inst.Pet., managing director of Esso Development Co. Ltd. since 1947, has been appointed general sales manager of Anglo-American Oil Co. Ltd. A vice-president of the Institute and chairman of its Council for 1947–8, Mr Tett entered the industry in 1928 in the Technical Sales Department of "Anglo". In 1935 he was appointed manager of that department, and in 1939 transferred to the International Association (Petroleum Industry) Ltd. During the war he served on numerous important committees and joined M.A.P. missions to the U.S.A. on the supply of 100 octane fuel.

Dr H. K. Whalley, F.Inst.Pet., head of the Chemical Research Department of Manchester Oil Refinery Ltd. since 1945, has now joined Petrocarbon Ltd. He will be in charge of programme and planning of Petrochemicals Ltd.

FORTHCOMING MEETINGS

INSTITUTE MEETINGS

The Viscosity of Aero-Engine Oils at Low Temperatures. S. G. Daniel. At 26 Portland Place, London, W.1, 5.30 p.m. (tea 5 p.m.), April 13.

Examination of Crude Oils in Relation to Geological Formations. F. Morton. At 26 Portland Place, London, W.1, 5.30 p.m. (tea 5 p.m.), May 11.

LONDON BRANCH

Oilfield Development. J. B. Kay. At 26 Portland Place, London, W.1, 6 p.m. (tea [1*s.*] 5.30 p.m.), April 26.

MEETINGS OF OTHER SOCIETIES

Fabrication of Chemical Plant in Stainless Steel. A. C. Branch and J. L. Sweeten. Institution of Chemical Engineers, at Geological Society, Burlington House, London, 5.30 p.m., May 17.

Scientific Information Services. Sir A. C. Egerton. Royal Society of Arts, London, 2.30 p.m., May 18.

The Geared Diesel Machinery of the Liner. "Willem Ruys." D. Ruys, Institute of Marine Engineers, London, 5.30 p.m., April 12.

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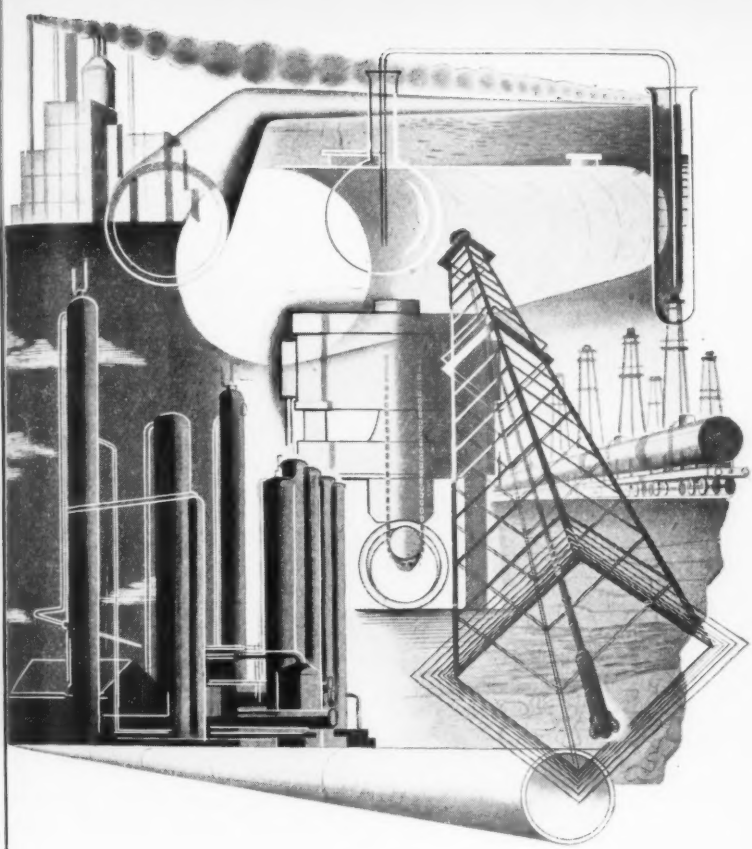

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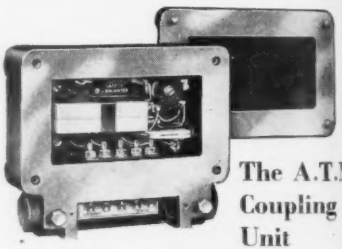
Direct Dialling

between telephones in safe and unsafe atmospheres

The A.T.M. auto-exchange coupling system enables fully automatic intercommunication to take place throughout an entire plant where petroleum atmospheres exist.

An intrinsically safe coupling unit and auto-repeater are fitted in the circuits which are extended into the hazardous areas. Dialling and speaking can then take place between persons in both the safe and unsafe areas through the automatic exchange which is installed in a safe area.

The system has been approved by the Factories Department (Certificate No. 44) for use in the presence of pentane vapour.



The A.T.M Coupling Unit

This unit permits through speech and ring... yet prevents the passage of dangerous voltages into t... unsafe area. It consists of a series impedance netw... shunted by a disc of "Atmite"—a compound which h... high impedance at normal signalling and speech voltag... but has a low impedance at higher voltages. The cha... to low impedance takes place at voltages well below t... dangerous level.

auto-exchange coupling system

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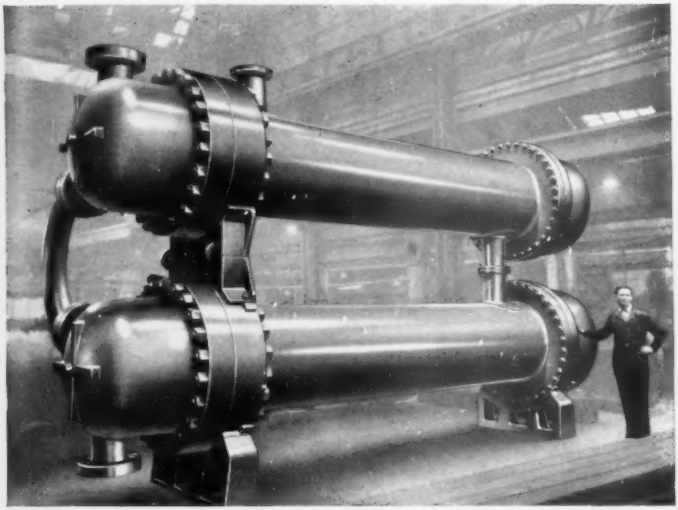
A6392-

HEAT EXCHANGE EQUIPMENT



HIGH PRESSURE HEAT EXCHANGERS

Surface per Unit	... ...	2170 sq. feet
Working Pressure in Tubes	...	1500 lb. per sq. inch

These two Units form part of a battery comprising 60 similar Units and having a Crude Oil throughput of 4½ million gallons per day.

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